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The Influence of Urban Runoff on Sediment Quality and Benthos in Toronto Harbour

Environmental Monitoring and Reporting Branch

June 2001

Ontario

Ministry of the Environment

THE INFLUENCE OF URBAN RUNOFF ON SEDIMENT QUALITY AND BENTHOS IN TORONTO HARBOUR

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1. Introduction

In a 1985 report to the International Joint Commission (IJC), the Great Lakes Water Quality Advisory Board recommended that appropriate jurisdictions prepare and submit detailed Remedial Action Plans (RAPs) for environmental restoration in 42 (now 43) Areas of Concern (AOCs) in the Great Lakes. In the Toronto waterfront "*restrictions on dredging*" and the "*degradation of benthos*" are two beneficial use impairments that prompted the designation of Metro Toronto as one of the 17 Canadian AOCs. In the RAP process indicators were identified to measure progress towards the restoration of beneficial uses. In the Toronto waterfront these indicators include the restoration of sediment that is: (a) inhabited by a healthy community of benthic invertebrates; and (b) free of dredging restrictions resulting from contamination.

There are generally three aspects to the assessment of sediment quality by the Ontario Ministry of Environment (MOE). These aspects include: (a) a screening level assessment of contaminated concentrations against the numerical *Provincial Sediment Quality Guidelines* (PSQGs); (b) assessment of benthic invertebrate species composition and density; and (c) assessment of toxicity. A range of sediment and suspended sediment sampling, benthic enumeration, and sediment toxicity work was undertaken in the Toronto waterfront from the 1970s to the mid-1990s (Persaud *et al.* 1985, Boyd 1986, Boyd 1988, Krantzberg *et al.* 1995) and the results have been incorporated into RAP reports (Environment Canada *et al.* 1988, MOEE and Environment Canada 1990, MOEE and Environment Canada 1992). These investigations concluded that sediment quality and benthos are degraded in the Inner Harbour, with concentrations of metals above the PSQG "Lowest Effect Levels" (LELs) at most locations and above "Severe Effect Levels" in the immediate vicinity of combined sewer overflows (CSOs). A key finding of these studies has been that highly contaminated sediment, such as that observed near CSOs, is extremely localized and attributable to ongoing sources. For example, Krantzberg *et al.* (1995) observed toxicity to benthic invertebrates (chironomid mortality, chironomid and mayfly growth inhibition) near CSOs that they attributed to active inputs of contaminants from diffuse urban sources (i.e. storm water runoff) and accidental or illegal industrial discharges to storm or combined sewers.

The majority of sediment in the harbour, while degraded, is not toxic to benthic invertebrates and does not have contaminant concentrations above PSQG "Severe Effect Levels". Direct intervention, such as dredging or in situ treatment at localized hot spots near CSOs has not been advised, since active sources have a high potential for re-contamination. Instead, a "natural recovery" option, focusing on control of urban non-point sources to urban watersheds and the Inner Harbour, has been advised. It is anticipated that this strategy will result in a substantial recovery of sediment quality with the benefits most readily observed in sheltered contaminated locations. This report examines the potential benefits of a natural recovery strategy more closely by comparing sediment quality trends with the results of tributary water quality and sewer monitoring undertaken in the early 1990s (Snodgrass and D'Andrea 1993, Maunder *et al.* 1995, Boyd *et al.* 1999).

2. Sources to Toronto Inner Harbour

Direct industrial or municipal sewage treatment plant sources to the Toronto Inner Harbour do not exist, rather, sediment in depositional areas is a repository for contaminants from a variety of local and non-local sources (i.e. storm sewers, combined sewer overflows, atmospheric deposition via tributary catchment areas). It is worth noting that the Portland and Bathurst CSOs in the extreme northwest comer of the harbour account for slightly more than half the estimated total flow from the 28 CSO and SS outfalls directly discharging to the harbour. It is also noteworthy that the Don River, the major tributary source to the harbour, is a highly urbanized watershed with approximately 30 CSO and 872 SS outfalls over its length. Two thirds of the land use in the Don River drainage basin (360 km^2) are classified as industrial, commercial, institutional, or residential, while 2% is classified as agricultural and 31% is designated as open space (Toronto and Region Conservation Authority 1998).

Contaminants typically associated with runoff include polycyclic aromatic hydrocarbons (PAHs), metals, petroleum hydrocarbons, suspended solids, nutrients, pesticides and bacteria. Sources include vehicles (exhaust, brake and tire wear, fuel and engine oil leaks or spills, and corrosion), sanitary sewer cross-connections, infiltration from the sanitary sewer system, accidental or deliberate spills to road side catch basins, chemical applications (fertilizers and pesticides), runoff from commercial/industrial storage areas, and faecal material from wildlife and domestic animals. In this report, suspended solids (in water), total phosphorus (TP), copper, lead, zinc and total PAHs have been used as indicators relevant to urban runoff, sediment quality, and the status of benthic invertebrate communities.

Suspended solids (including inorganic material like silt and clay, and particulate organic matter such as algae) are a principal factor in the determination of water clarity, although discolouration associated with dissolved solids is also a factor. Typical concentrations of suspended solids, throughout much of the year, do not cause direct stress to aquatic life or impose undue restrictions on beneficial uses such as recreation. They are, however, strongly associated with contaminants such as metals and trace organics which have low solubility and tend to preferentially bind to suspended solids. Analysis of centrifuged particulates from the Don River (Boyd 1988) confirmed that a significant proportion of the phosphorus and metals delivered to the harbour are associated with suspended sediment. For example, estimates of phosphorus partitioning range from about 20% to 90% particulate, with a median of approximately 40%. Similar median results were found for copper, lead, and zinc.

The effect of the Don River, as well as direct discharges from CSO and SS outfalls, on sediment and biota in the Inner Harbour depends upon the depositional environment in the harbour and the quantity and quality of suspended sediment loads. The harbour provides a relatively sheltered environment for sedimentation. Examination of dredging records for the Keating Channel (in the northeast corner of the harbour at the mouth of the Don River), sediment trap accumulation rates, flow patterns, wave climate and sediment type indicates that the Inner Harbour acts as a sediment trap for a large proportion of the total suspended sediment that is delivered to it.

Metals are good tracers of a wide range of industrial activity, as well as urbanization. Copper, lead, and zinc are frequently detected in the waters and sediment of southern Ontario. The use of copper piping is a direct source of enrichment in urban settings as most household water will have traveled through copper pipe as part of the supply system. Copper is also used in metal alloys, wiring, insecticides and fungicides and consequently can be a tracer of a wide range of urban land use practices. The use of lead as a fuel additive (until it was phased out in the 1980s), in paint, as solder and as shot accounts for the ubiquitous nature of lead in urban soil, sediment and water. Although zinc is an essential element for plant and animal nutrition, its use in metal galvanizing and plating, as well as in dyes and paints, means that elevated concentrations can be observed in urban and industrial watersheds.

The locations of CSO and SS discharges to the Inner Harbour are illustrated in Figure 2.1. Tables 2.1 demonstrates the relative significance seasonal flows and contaminant loads from these sources. For comparative purposes, and consistency among CSO and SS monitoring studies, runoff volumes for sewer outfalls are presented based on a 1980 "standard" rainfall distribution for the period extending from May 01 to October 31 (Maunder *et al.* 1995).

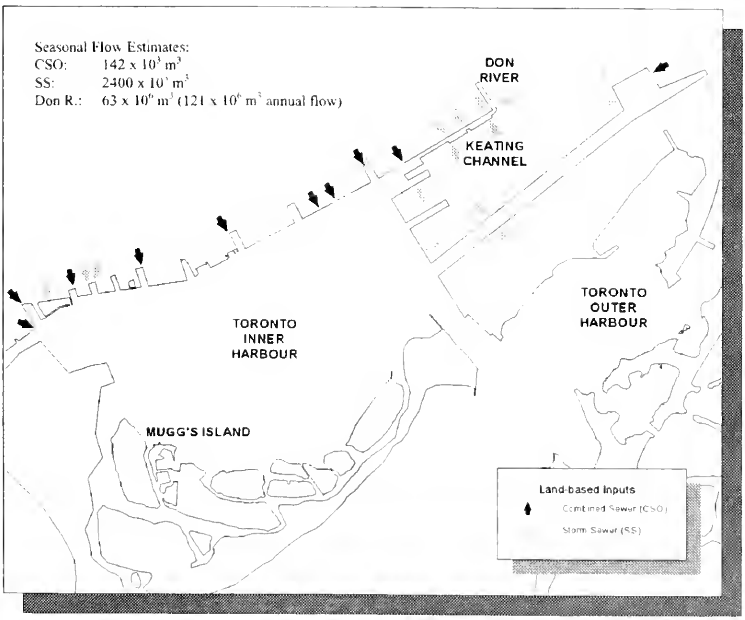

Figure 2.1: Land-based Inputs to Toronto Harbour (Maunder *et al.* 1995; Boyd *et al.* 1999)

Table 2.1: Land-based Inputs to Toronto Harbour (Boyd 1988; Maunder *et al.* 1995; Boyd *et al.* 1999)

		Proportional Contribution to Toronto Harbour by Source (%)		
	Seasonal Flow/Load	Don River	Combined Sewer Overflows (CSO)	Storm Sewers (SS)
Flow	63×10^6 m^3	96	4	0
Suspended Solids	9.8×10^6 kg	92	8	0
Copper	1.6×10^3 kg	92	14	0
Lead	2.8×10^3 kg	95	10	0
Zinc	5.6×10^3 kg	94	11	0
Total PAH	4.7×10^1 kg	77	22	1
Total Phosphorus	2.3×10^4 kg	85	14	1

The highly-urbanized Don River is the dominant source of flow and contaminant loading to the harbour. The river accounts for over 90% of land-based flow to the harbour. Since contaminant loads are positively correlated with flow, the river also accounts for a majority of the suspended sediment, phosphorus, copper, lead and zinc loading. The relative contribution of total PAH load to the harbour from the CSOs is substantially higher than other contaminants at 22%, but the Don River still dominates the overall load.

Summarized data for these same contaminants in the Don River (dry and wet weather), as well as SS and CSO discharges, are presented to illustrate further the relative significance of varying sources to the harbour (Figures 2.2 to 2.7). Even though loadings to the harbour are dominated by flows from the Don River, the data demonstrate that CSO and SS discharges contain the highest contaminant concentrations. CSO and SS effluents can result in significant localized water and sediment quality degradation, despite the relative insignificance of these sources in total loading to the harbour. Dry weather flows in the Don River represent the lowest contaminant concentrations while, not surprisingly, CSO discharges represent the most degraded water quality. Wet weather flows in the Don River and SS discharges fall in between these two extremes. Although the dry weather river water is of higher quality than CSO and SS effluents, it should be noted that the mean concentrations of phosphorus, copper and lead all fail to meet their respective Provincial Water Quality Objectives of 30 µg/L, 5µg/L and 5 µg/L.

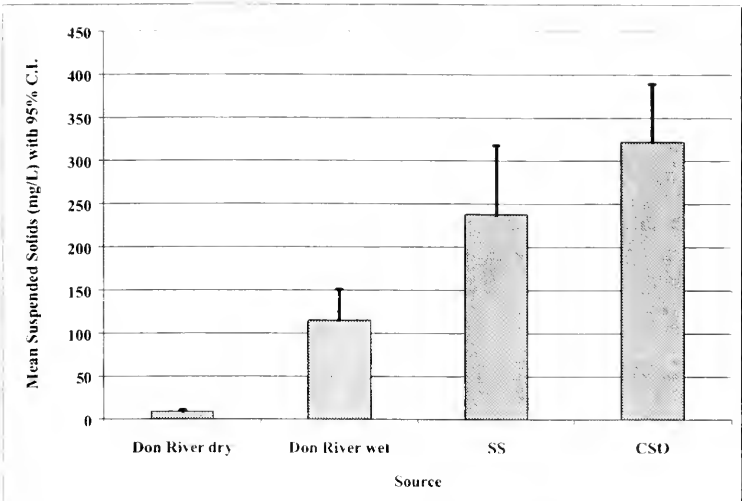

Figure 2.2: **Comparison of Suspended Solids Concentrations in Sources to Toronto Harbour (Maunder *et al.* 1995; Boyd *et al.* 1999)**

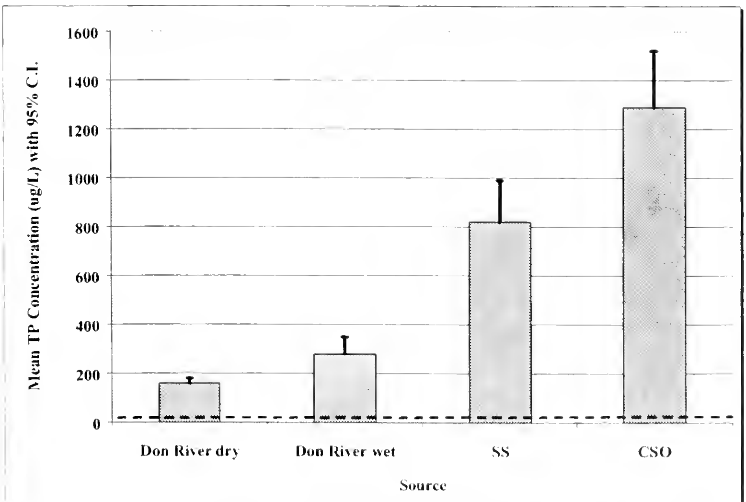

Figure 2.3: **Comparison of Total Phosphorus Concentrations in Sources to Toronto Harbour (Maunder *et al.* 1995; Boyd *et al.* 1999)**

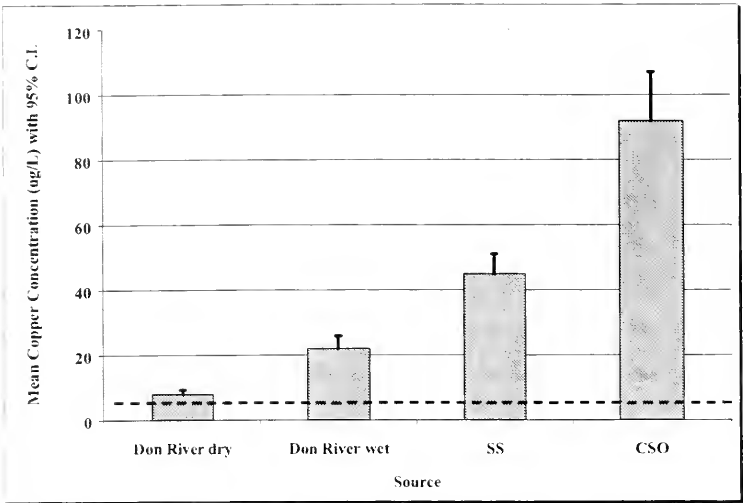

Figure 2.4: Comparison of Copper Concentrations in Sources to Toronto Harbour (Maunder *et al.* 1995; Boyd *et al.* 1999)

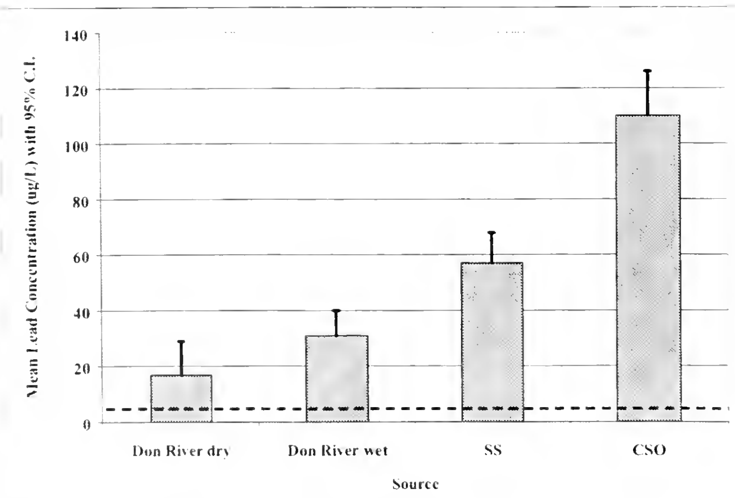

Figure 2.5: Comparison of Lead Concentrations in Sources to Toronto Harbour (Maunder *et al.* 1995; Boyd *et al.* 1999)

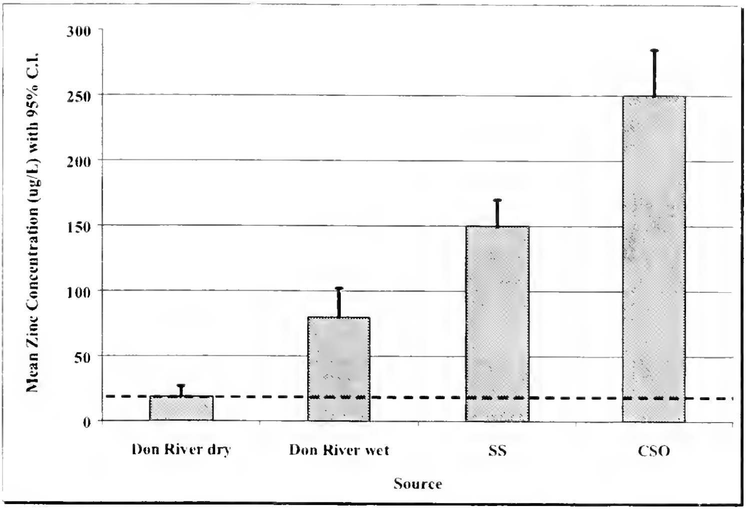

Figure 2.6: Comparison of Zinc Concentrations in Sources to Toronto Harbour (Maunder *et al.* 1995; Boyd *et al.* 1999)

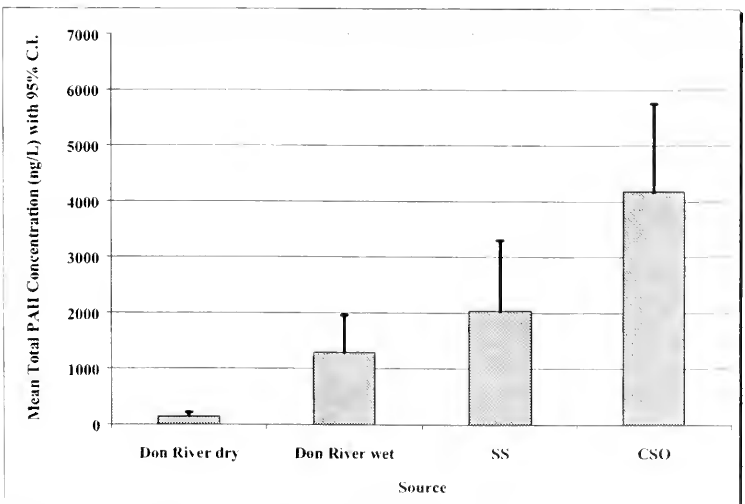

Figure 2.7: Comparison of Total PAH Concentrations in Sources to Toronto Harbour (Maunder *et al.* 1995; Boyd *et al.* 1999)

Although trend data are not available for CSO and SS discharges, a long-term record is available for the lower Don River (at the Todmorden flow gauge). It is reasonable to hypothesize that trends in the quality of urban runoff will be reflected in water quality data for the river. Results of water quality sampling in the lower Don River undertaken by MOE over the period 1980 to 1999 (no sampling in 1997) are summarized in Figures 2.8 to 2.10. Sample sizes varied over this period, with n > 35 in nine of the 18 years, and n > 70 over the period 1992 to 1995. Data have been pooled into three-year samples and moving, flow-weighted means have been calculated and plotted (along with unit-area loads) for suspended solids, phosphorus, and lead. A strong positive correlation exist often between flow and contaminant concentrations, particularly those contaminants associated with suspended solids. Year-to-year variability in contaminant concentrations and loads tends to be controlled by variability in flows. The procedure presented here is intended to diminish the influence of variability in flow in order to observe any underlying trends.

Results for suspended solids show no evidence of a trend. It is apparent that suspended solids concentrations in the 1990s are similar to those observed in the early 1980s, although conditions have fluctuated over the intervening period. Sediment loads to Toronto Harbour from the Don River are highly variable and have not demonstrated a decreasing trend over the past 20 years.

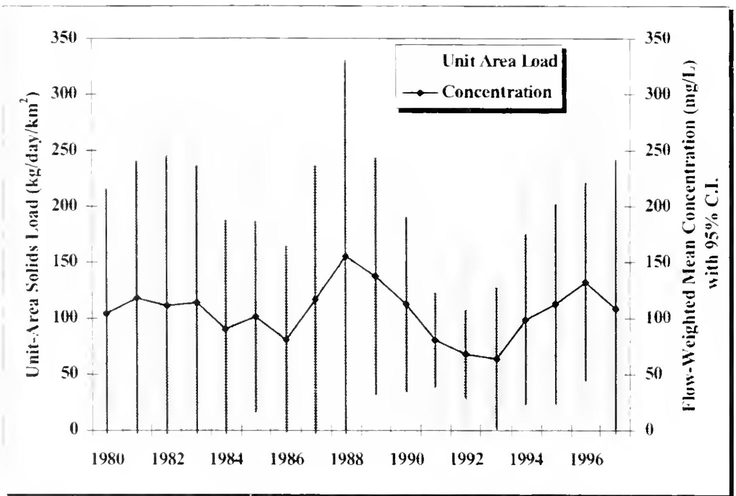

Figure 2.8: **Long-term Water Quality Trends for Suspended Solids in the Don River (MOE Enhanced Tributary Monitoring Data).**

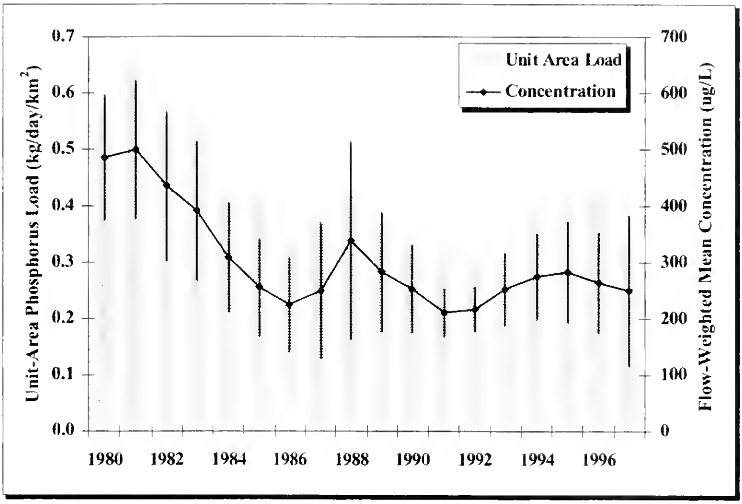

Figure 2.9: Long-term Water Quality Trends for Total Phosphorus in the Don River (MOE Enhanced Tributary Monitoring Data).

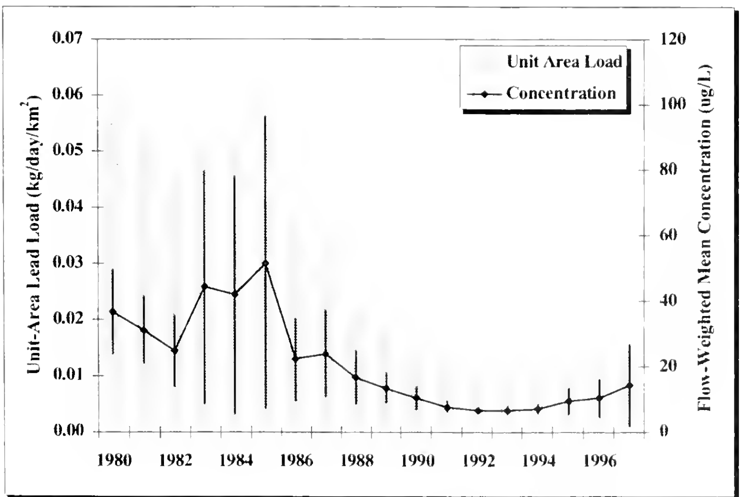

Figure 2.10: Long-term Water Quality Trends for Lead in the Don River (MOE Enhanced Tributary Monitoring Data).

Phosphorus and lead, on the other hand, exhibit long-term reductions in flow-weighted means (and unit-area loads) with relative reductions of 40% and 75% respectively. The relatively large reduction in unit-area loads of lead from the early 1980s to the late 1990s reflects the transition to lead-free fuels during the 1980s. Although the reductions for phosphorus are less dramatic, these data suggest that the quality of urban runoff inputs to the Don River, including storm water and discharges from the North Toronto STP, improved over this period.

Although the data presented in Figure 2.9 and 2.10 cannot be used to predict future trends, it is apparent that flow-weighted concentrations and unit-area loads were at their lowest in the early 1990s for total phosphorus and lead and there have been no improvements since then. The apparent increase visible in the graphs is not meaningful given the variance in the data as indicated by the 95% confidence interval bars on the graph. Although significant improvements have been achieved since the early 1980s, additional effort would be required to achieve further reductions in concentrations of phosphorus and lead in the Don River and loads of other contaminants to Toronto Inner Harbour.

A final demonstration of the relationship between water quality in the Don River and the Harbour is shown in Figure 2.11. The water quality map shows phosphorus concentrations measured in surface water throughout the harbour in August 1997 following a rainfall event. This map clearly illustrates a steep concentration gradient at the mouth of the Don River and shows the significance of the river in dictating water quality conditions throughout the harbour. Given that in 1997 open-lake concentrations of total phosphorus were approximately 8 µg/L, it is evident that harbour water is nutrient-enriched relative to Lake Ontario. This is not of direct significance when considering sediment chemistry but is relevant to interpretation of the benthic community status.

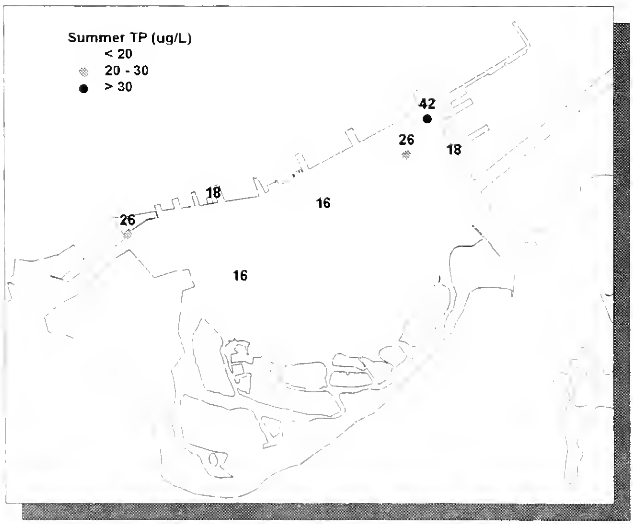

Figure 2.11: 1997 Toronto Harbour Water quality, Summer Total Phosphorus Concentrations (MOE Great Lakes Harbour Reconnaissance Data)

3. Toronto Inner Harbour Benthos and Sediment Toxicity

Figures 3.1 and 3.2 illustrate biological conditions associated with harbour sediment in 1995 by mapping benthic community status and sediment toxicity results. Oligochaetes formed the largest component of the benthic community at all locations. With the exception of a few locations near the Toronto Islands, oligochaetes comprised between 75% and 100% of the benthic community and were represented by a number of species, most commonly *Limodrilus* spp., *Quistadrilus multisetosus* and *Potamothrix moldaviensis*. These taxa are typical of enriched areas. Chironomids comprised only a small component of the benthic community.[1]

Other groups were present as minor components of the benthic community. Molluscs were observed at the majority of stations, and were most often represented by the fingernail clam *Pisidium*, which are typically found in soft sediments. Noteworthy was the presence of the zebra mussel (*Dreissena polymorpha*) at a number of stations. Zebra mussels have not been encountered during previous surveys of the harbour. While zebra mussels are usually considered inhabitants of hard substrates, they were observed in the harbour in areas of fine (soft) sediments.

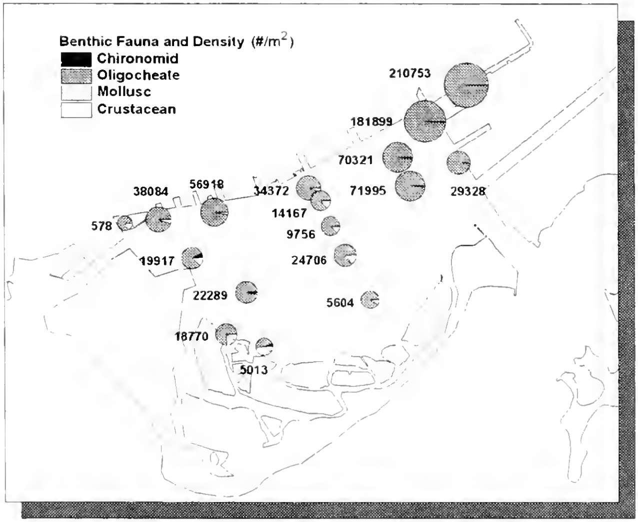

Figure 3.1: Benthic Invertebrate Enumeration (1995)

A 1995 assessment of sediment toxicity within Toronto Harbour showed no significant effect on the survival of aquatic mayflies (*Hexagenia limbata*), midge larvae (*Chironomus tentans*) or fathead minnows (B.A.R. 1996). Exposure to sediments from Toronto Harbour sites resulted in no reduction in growth of midge larvae, rather, the larvae either increased in size or were unaffected. However, all Toronto Harbour sediment samples imparted a decrease in growth of aquatic mayflies relative to sediments collected from a control site (Lake Erie, Long Point). This level of impairment (i.e. growth inhibition of mayflies) is within expected limits for sediment collected in a depositional environment adjacent to a large urban centre.

[1] This observation may be attributable to, in part, the sampling period. Samples were collected in September and October while most chironomids emerge in late spring and summer. As a result, predominantly early instars would have been present by the fall. These instars could have readily passed through the sieve and may account for the low density and diversity in most samples.

Throughout most of the harbour, the benthic community distribution does not appear to be related to the distribution of nutrients or contaminants in sediment. In some areas of higher benthic diversity, levels of some contaminants (i.e. copper, lead and zinc) were higher than those areas off the Keating Channel where benthic organism diversity was very low. The similarity in spatial gradients between benthic community structure and the nutrient status of harbour water (Figures 2.11 and 3.1), on the other hand, strongly suggests that trophic status is a significant determining factor for benthic community status throughout much of the harbour, and at the mouth of the Don River in particular. Median 1997 phosphorus concentrations in water at 1995 benthic sampling locations correlate well with oligochaete densities (r^2=0.99, n=6).

A predominance of oligochaetes in the benthic community is a well recognized indicator of eutrophication. Steep gradients in concentrations of TP at the mouth of the Don River indicate the effect of consistently elevated TP concentrations in river water despite the relatively low TP background in Lake Ontario. It is interesting to note that the distribution of oligochaetes observed in 1995 was similar to earlier studies such as the one conducted by Brinkhurst (1970) in 1969. This suggests that despite significant improvements in water quality in the last three decades, the influx of nutrients, sediment, and organic matter from the Don River are still sufficient to maintain eutrophic conditions in the northeast corner of the harbour.

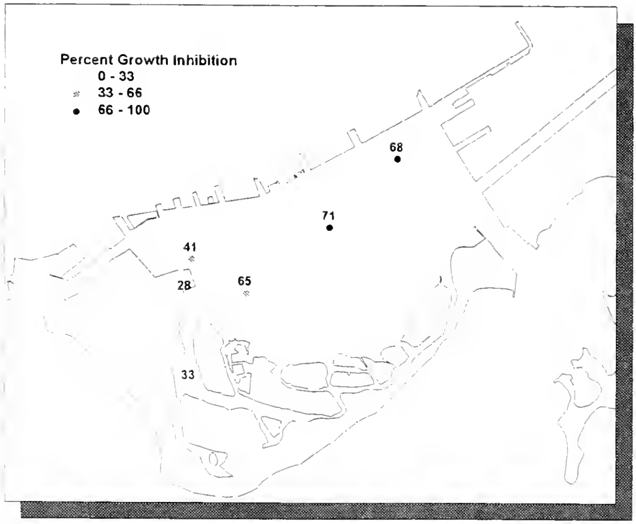

Figure 3.2: Sediment Toxicity – Mayfly Growth Inhibition (1995)

Sediment bioassays demonstrating the absence of lethal effects from exposure to sediment are a good indication that the direct toxic effects on benthos are not an issue at most sites in the Inner Harbour, with the probable exception of the northwest corner near the Bathurst and Portland CSO discharges. Contaminant concentrations may have been a factor in the relatively low density of benthic organisms at this location (~500 m^{-2}) when compared to other stations in the harbour. Previous bioassays on sediment near the Jarvis CSO discharge have demonstrated significant mortality to chironomids (Krantzberg *et al.* 1995) where concentrations of copper and lead were above PSQG/SEL values. The observed growth inhibition of mayflies demonstrates that current levels of nutrients, as well as the influence of other pollutants such as metals, continues to limit colonization by pollution sensitive species.

4. Toronto Inner Harbour Sediment Chemistry and Trends

Sediment quality assessments have been undertaken since the mid 1970s by MOE, Environment Canada and the Toronto and Region Conservation Authority (TRCA). This historical record provides a baseline against which current conditions can be compared. Sediment has been analyzed for a variety of contaminants including PCBs and organochlorines, PAHs, trace metals, nutrients and a variety of physical parameters such as grain size and loss on ignition.

Recent and historical sediment chemistry results are illustrated in Figures 4.1 to 4.17 along with a summary of the relative degree of change at selected locations. Particle size corrected concentration gradients are also included as a means of inferring sources.[2]

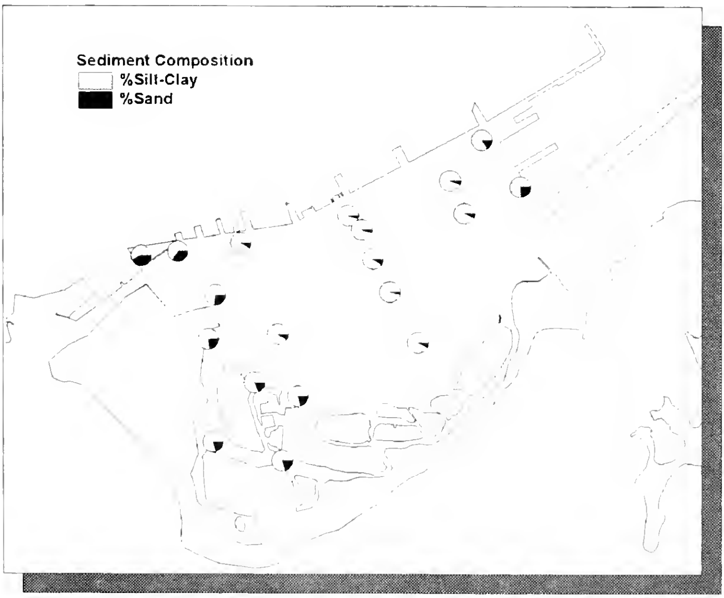

Figure 3.1: Toronto Harbour Sediment Particle Size (1995)

[2] Contaminant concentrations, particularly metals, tend to be strongly correlated with the proportion of fine grained sediment. Normalizing the bulk sediment chemistry for particle size by scaling the data to a common proportion of silt/clay (i.e. 100% < 63 µm particle size) diminishes the relative significance of particle size, and hence depositional environment, on sediment chemistry and increases the relative significance of other factors such as proximity to a source.

The maps illustrate that sediment conditions are relatively uniform throughout the Inner Harbour with a preponderance of organically and nutrient-enriched, fine-grained material at all stations. Sites in the northwest corner of the harbour (near the Bathurst and Portland CSO discharges) and in the Toronto Island area in the southwest (south of Mugg's Island and the Toronto Island Yacht Club) are notably enriched with total phosphorus (TP) and have slightly elevated concentrations of total organic carbon (TOC).

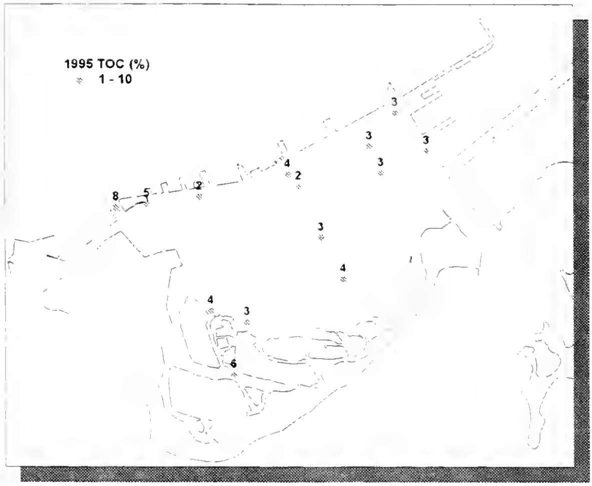

Figure 4.2: 1995 Toronto Harbour Sediment Total Organic Carbon

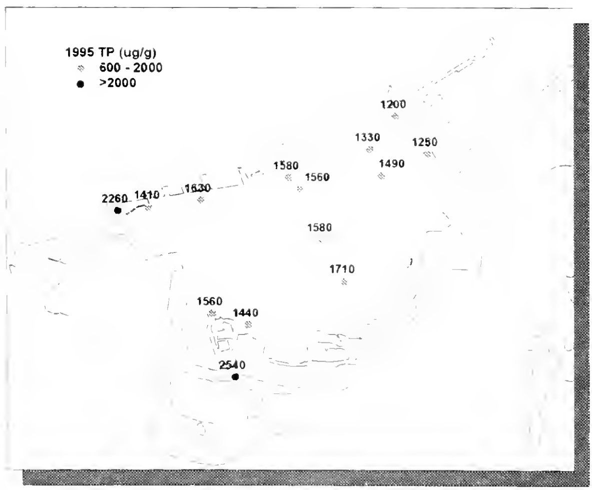

Figure 4.3: Toronto Harbour Sediment Total Phosphorus

Copper

In 1995, copper concentrations exceeded the Provincial Sediment Quality Guidelines (PSQG) "Severe Effect Level" (SEL)[3] at the same locations that exhibited nutrient and organic enrichment (i.e. in the northwest corner, south of the Island Yacht Club and Toronto Island Marina near Mugg's Island). Concentrations south of Mugg's Island were marginally above the SEL value of 100 μg/g, but in the vicinity of the Bathurst and Portland CSO discharges the concentration was more than double the SEL guideline at 260 μg/g (Figure 4.4). Concentrations at other stations were well above the PSQG "Lowest Effect Level" (LEL) of 16 μg/g, ranging from approximately 70 μg/g to 100 μg/g.

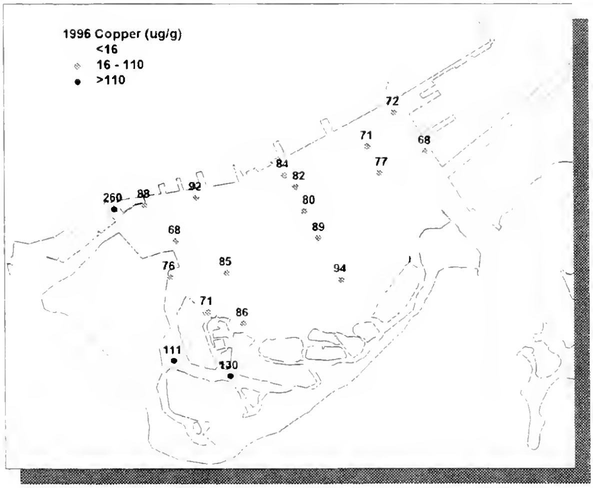

Figure 4.4: 1995 Toronto Harbour Sediment Copper Concentrations

Concentration gradients, normalized to 100% silt/clay (Figure 4.5), suggest that the CSO discharges in the northwest corner are a significant localized source of copper to sediment[4]. These gradients are also of interest in that they do not identify the Don River in the northeast comer as a significant local source. This may be due to the sampling location in the 1995 harbour study area downstream of the Keating Channel. The Channel acts as a sediment trap for suspended sediment delivered by the Don River and requires ongoing maintenance dredging.

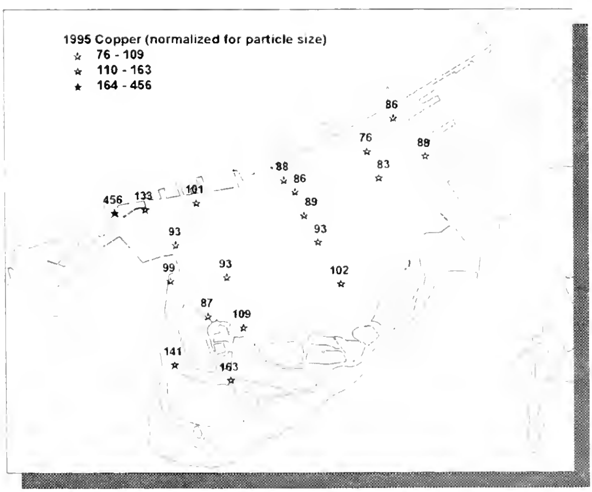

Figure 4.5: 1995 Toronto Harbour Sediment Copper Concentration Gradients (normalized to 100% silt/clay)

In 1978 peak copper concentrations were also evident in the northwest corner of the harbour, however, they were only slightly above the SEL guideline (Figure 4.6). Concentrations at other stations were generally lower then in 1995. Mapping the relative change in copper concentrations[5] over the period 1978 to 1995 (Figure 4.7) demonstrates a pattern of degradation throughout the harbour, particularly in the vicinity of the CSO discharges in the northwest, and around Mugg's Island. There is also evidence of slight deterioration in sediment quality in the north central and northeastern areas of the harbour.

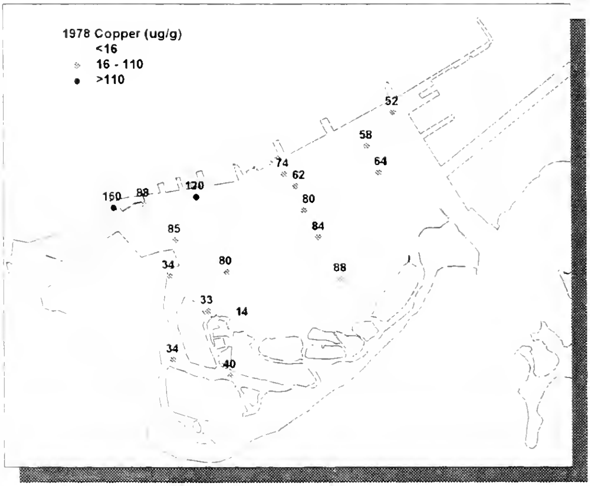

Figure 4.6: 1978 Toronto Harbour Sediment Copper Concentrations

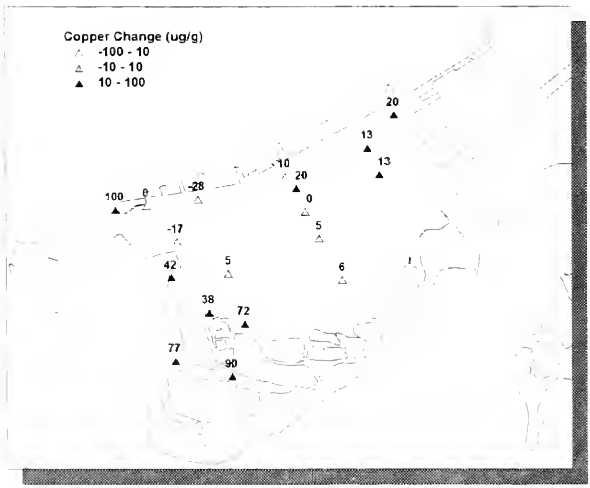

Figure 4.7: Change in Toronto Harbour Sediment Copper Concentrations (1978 – 1995)

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[3] The SEL is the contaminant concentration expected to be detrimental to the majority of benthic species.

[4] These concentration gradients have not been labeled as µg/g since they are computed values. The gradients, rather than the concentrations, are of interest.

[5] The relative change has been mapped by subtracting the 1978 concentration from the 1995 concentration for locations sampled in both years. The significance of these relative changes has been classified according to the 95% confidence intervals computed at three 1995 harbour stations where triplicate sampling was undertaken.

Lead

In 1995 lead was detected at concentrations slightly exceeding the SEL guideline of 250 µg/g near the Portland and Bathurst CSO discharges and south of Mugg's Island (Figure 4.8). Concentrations at other locations throughout the harbour ranged from less than twice the LEL guideline of 32 µg/g in the northeastern zone of the harbour to nearly 200 µg/g in the western and southern zones of the harbour.

The particle size-normalized concentration gradients for lead are more variable than for copper but still point to the CSO discharges in the northwest corner as a local source (Figure 4.9). The gradient map provides no indication of the Don River as a significant local source.

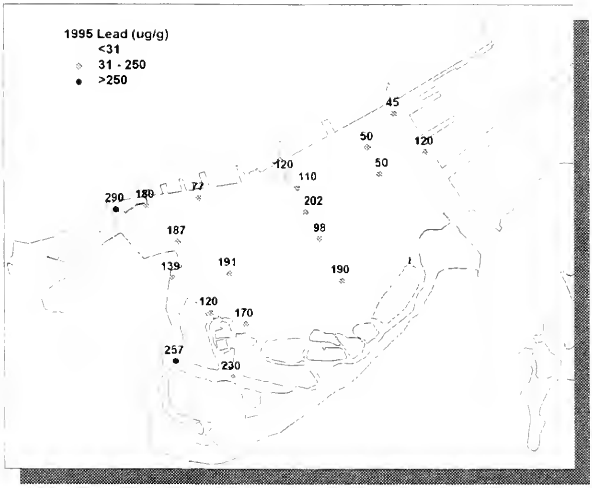

Figure 4.8: **1995 Toronto Harbour Sediment Lead Concentrations**

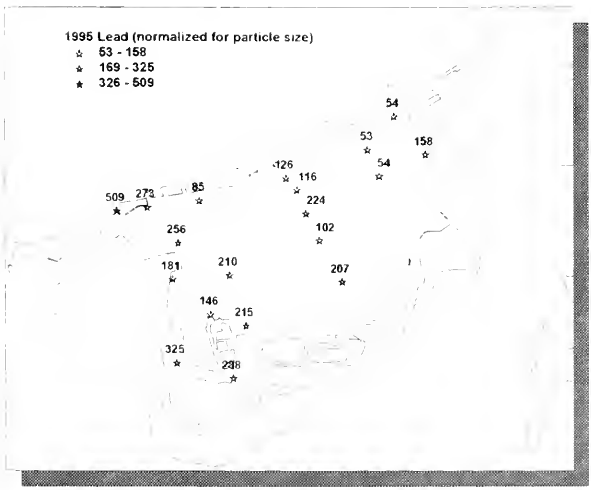

Figure 4.9: **1995 Toronto Harbour Sediment Lead Concentration Gradients (normalized to 100% silt/clay)**

In 1978 conditions were very different. Lead concentrations greatly exceeded the SEL guideline for lead in the northwest corner, and were slightly above and below 250 µg/g at most locations throughout the harbour (Figure 4.10). The only exception was the southwest zone near the Toronto Islands. Mapping the relative change in lead concentrations between 1978 and 1995 (Figure 4.11) reveals significant improvement throughout most of the harbour and spectacular improvement in the northwest corner near the CSO discharges. It is apparent the some degradation occurred in the southwestern zone, particularly south of Mugg's Island and near the Island Yacht Club and the Toronto Island Marina.

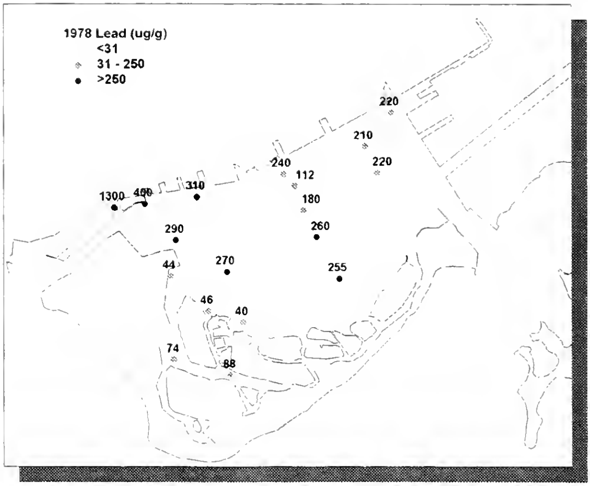

Figure 4.10: 1978 Toronto Harbour Sediment Lead Concentrations

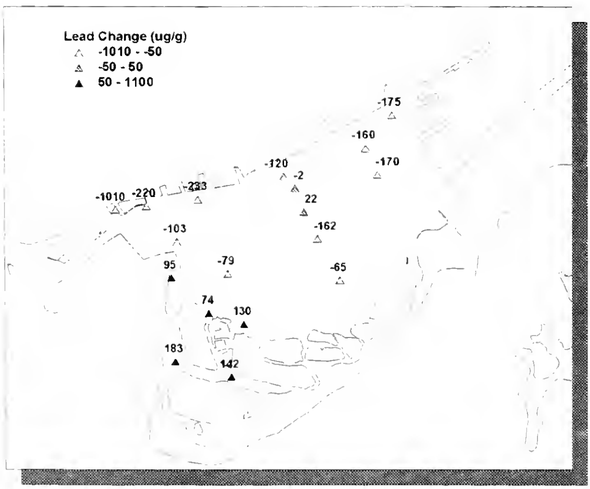

Figure 4.11: Change in Toronto Harbour Sediment Lead Concentrations (1978 – 1995)

Zinc

In 1995 there were no observed zinc concentrations in excess of the SEL guideline of 820 µg/g anywhere in the harbour (Figure 4.12). With the exception of the northwest corner zinc concentrations in 1995 were relatively homogenous throughout the harbour. The peak concentration of 560 µg/g near the Portland and Bathurst CSO discharges was still well below the SEL guideline. Particle size normalized gradients in zinc concentrations (Figure 4.13) once again point to the CSO discharges as a significant local source and fail to reveal a localized influence from the Don River. These gradients also suggest some localized effect in the southwest area near Mugg's Island.

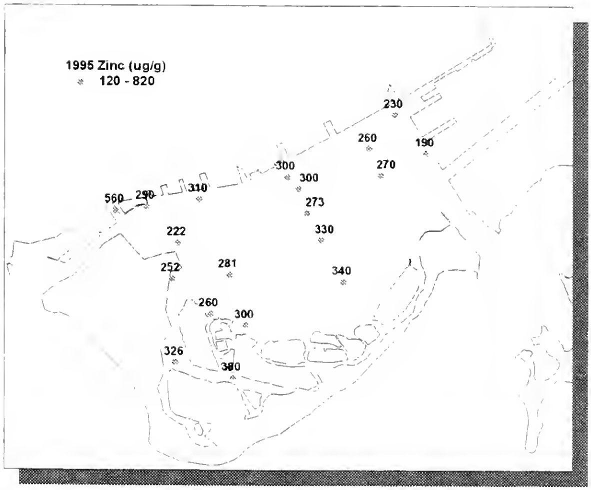

Figure 4.12: 1995 Toronto Harbour Sediment Zinc Concentrations

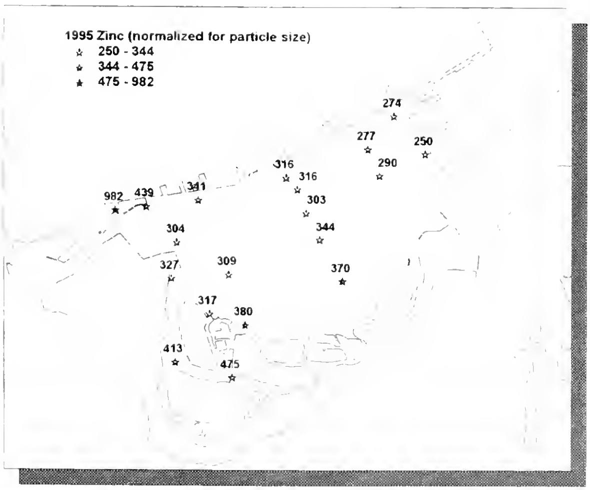

Figure 4.13: 1995 Toronto Harbour Sediment Zinc Concentration Gradients (normalized to 100% silt/clay)

Concentrations of zinc in sediment were generally higher in 1978, with the highest concentrations observed in the northwest corner and just east of the main ferry docks in the north-central area of the harbour (Figure 4.14). These peaks were below the SEL guideline. Mapping the relative change in the zinc concentrations (Figure 4.15) illustrates a pattern of improvement in the northern portion of the harbour but, as with copper and lead, some considerable deterioration in sediment quality is evident in the southwestern area.

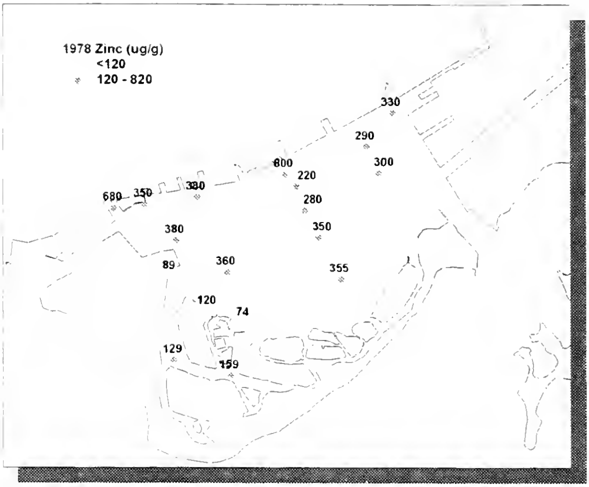

Figure 4.14: 1978 Toronto Harbour Sediment Zinc Concentrations

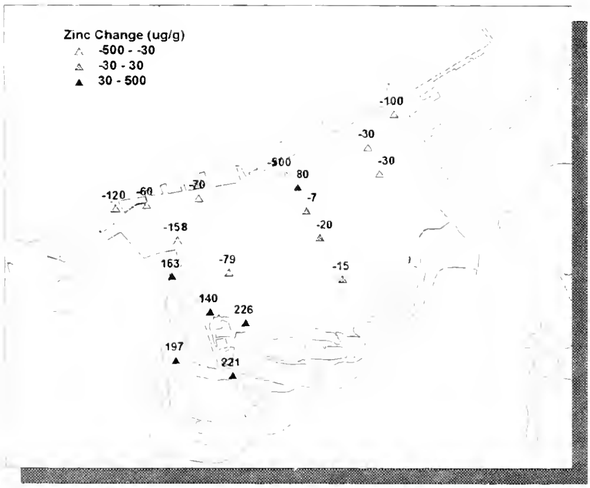

Figure 4.15: Change in Toronto Harbour Sediment Zinc Concentration Gradients (1978 – 1995)

PAHs

Historical concentrations of PAHs in sediment are not available, but the concentrations observed in 1995 (Figure 4.16) are well below the SEL guideline of 200 µg/g to 800 µg/g depending upon the location.[6] Concentrations ranged from below the LEL guideline of 4 µg/g south of Mugg's Island to approximately ten times greater than this in the vicinity of the Bathurst and Portland CSO discharges. Like metals, normalizing PAH concentrations for particle size points to the discharges in the northwest corner as significant local source. However, unlike the metals, this procedure also identified some effect from the Don River in the northeast corner of the harbour and does not indicate any local effect in the vicinity of Mugg's Island (Figure 4.17).

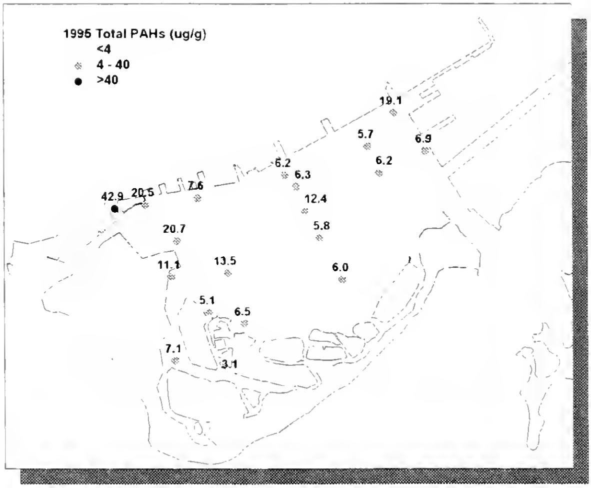

Figure 4.16: 1995 Toronto Harbour Sediment Total PAH Concentrations

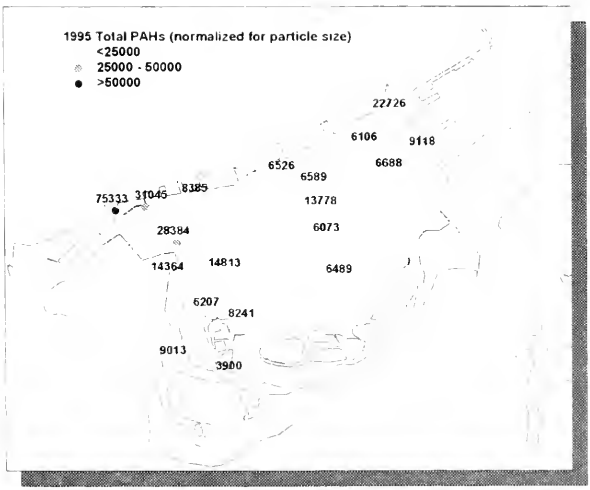

Figure 4.17: 1995 Toronto Harbour Sediment Total PAH Concentration Gradients (normalized to 100% silt/clay)

[6] The SEL for total PAH is 10,000 µg/g organic carbon. TOC varied from between 2% and 8% throughout the harbour.

5. Conclusions and Recommendations

Conclusions

1. Since the late 1970s, some progress has been made toward the RAP goal of restoring sediment that is inhabited by a healthy community of benthic invertebrates where dredging activity is not limited by contaminants. Currently, the benthic invertebrate community throughout most of the harbour is a reflection of trophic status, not sediment contamination by metals, and is limited by phosphorus (TP) enriched water from the Don River as well as CSO and SS discharges.

2. Sediment (and water) quality conditions in the immediate vicinity of CSO and SS discharges dictate the local biological response despite the relative insignificance of these sources from the perspective of total loading to the harbour. In the northwest corner of the harbour, the Bathurst and Portland CSO discharges have made this local effect observable on a larger scale than elsewhere in the harbour.

3. Improvements in the quality and quantity of direct CSO and SS discharges can be expected to yield significant local benefits (particularly in the northwest corner) despite the overall marginal impact on total contaminant loads to the harbour. Improvements in the quality and quantity of CSO and SS discharges to the Don River can be expected to improve conditions in the river which will, in turn, improve conditions in the harbour.

4. Conditions in the harbour suggest that the RAP strategy of "natural recovery" is sound, since direct intervention through sediment removal or treatment is not likely to be biologically warranted except in the vicinity of the SS and CSO discharges, and sites near active sources are not good candidates for this type of intervention.

5. The rate of progress towards a "healthier" benthic community throughout most of the harbour will depend primarily on Don River water quality, particularly its nutrient (TP) status. Current trends suggest that it is not realistic to expect significant change in the benthic community structure, particularly in the northeast corner of the harbour, unless significant reductions of nutrient sources are achieved in the Don River watershed.

6. Significant improvement in sediment quality has been achieved throughout much of the harbour since the late 1970s, particularly for lead, but also for copper and zinc. This suggests that water quality in the Don River and sediment quality in the harbour have been directly and positively influenced by the elimination of sources such as leaded gasoline, as well as a range of other activities to reduce contaminant loads related to urban non-point sources. These activities could include the increased use of buffer strips to act as pollutant traps, sewer use and spills control programs, and improved sediment and erosion control practices, but apart from lead it is difficult to identify the specific management practices that can account for the improving trends.

7. The rate of progress toward the RAP goal of sediment quality that no longer restricts dredging activity will depend on localized improvements near SS and CSO discharges, since these are typically situated in boat slip where dredging may periodically become necessary. Significant local improvement could also be expected in areas where flows from SS and CSO discharges are eliminated entirely, but trends in urban storm-water quality (as reflected in the Don River) suggest that conditions have not improved since the early 1990s and the current storm-water management practices will not be sufficient to effect further improvements in sediment quality.

8. Despite improvements in sediment quality for lead and zinc throughout much of the harbour, there is evidence of sediment quality degradation. Sediment copper concentrations have increased slightly in the northeast portion of the harbour, and significant deterioration is evident in the northwest corner and near the marina and yacht club situated near Mugg's Island in the southwest. This trend may reflect, in part, harbour-specific sources such as anti-fouling paints used extensively on boat hulls.

9. Localized degradation in sediment quality for lead and zinc was also observed in the southwestern area of the harbour near Mugg's Island. This area is the site of boat traffic associated with the Island Yacht Club and Toronto Island Marina. Since this zone is not directly influenced by SS and CSO discharges, or the Don River, a lack of improvement relative to the rest of the harbour is not surprising. The increases in local concentrations of lead and zinc, however, suggest that local sources have increased since 1978.

Recommendations

1. The RAP should consider further clarification of the sediment-related targets associated with benthic invertebrates and sediment quality. Given the apparent relationship between water quality nutrient status and the benthic community throughout much of the harbour, a revised target for a healthy benthic invertebrate community should distinguish between impairment attributable to water quality and that associated with sediment quality. It may also be worthwhile to assess the feasibility of eliminating restrictions on dredging associated with sediment chemistry (i.e. disposal of dredged material) in a highly urbanized waterfront.

2. The development and implementation of a Wet Weather Master Plan for the City of Toronto will play a significant role in urban storm-water quality and quantity, as will the recently approved sewer-use bylaw. As illustrated in this report, there is a direct (if complex) relationship between urban storm-water management and sewer use, the quality of the water in the Don River, sediment quality in the Toronto Inner Harbour, and the population of benthic invertebrates on a harbour-wide and local scale. Although predicting the degree of improvement associated with specific management activities will not be easy, these forecasts should include an accounting of all potential localized benefits. The traditional reliance on estimation of loading reductions will tend to undervalue the benefits from a water and sediment habitat perspective.

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